

Wheeler & Cutsforth.

The role of synaesthesia in learning.

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THE RÔLE OF SYNÆSTHESIA IN LEARNING

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Introduction.—A preliminary analysis of a case of synæsthesia by means of the introspective method clearly indicated that it was worth while to undertake several intensive studies of the phenomena first, for the reason that detailed introspective descriptions even from one trained synæsthetic reagent seemed to throw considerable light upon the nature and functioning of synæsthesia itself and upon several systematic problems the status of which seems to be in doubt as far as experimental results are concerned. Secondly, since our synæsthetic reagent is blind and since we were able to check his introspections against a second blind reagent who is asynæsthetic,¹ it seemed worth while to contribute indirectly to the literature on the psychology of the blind.

The purpose of this particular investigation was to ascertain the value and functioning of synæsthetic processes in learning and to draw such conclusions as might be possible regarding the nature of synæsthesia itself from a functional point of view.

Method, Apparatus and Observers.—Observer *A* is a graduate student at the University of Oregon with four years of introspective training. Observer *B* is likewise a trained introspector and was a major student of advanced standing at the time his introspections were obtained. *A* lost his sight at the age of eleven and *B* at the age of nine. *B* was employed as a 'check' reagent.

The material for this investigation consisted of two sets of nonsense syllables, one for tactual presentation and one for auditory presentation. Each set contained four series of

¹The term 'asynæsthetic' was suggested to the senior author by Dr. Edwin G. Boring to designate a person's mental equipment which is not synæsthetic.

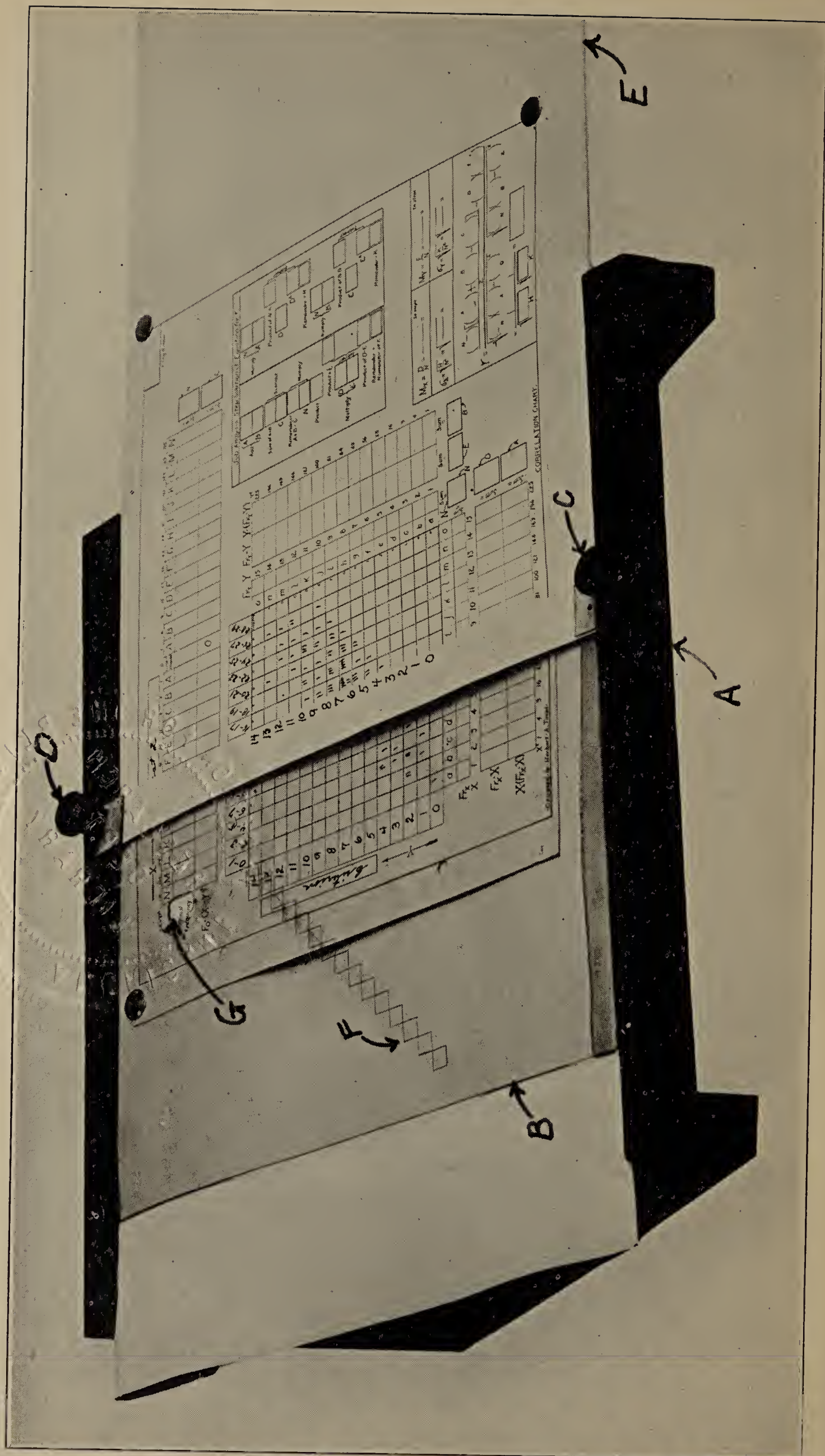


FIG. 3. A correlation plotting device

ten syllables each. The syllables for tactual presentation were punched by a Braille machine on rectangular pieces of tag-board 5×10 centimeters in size. These cards were placed on the table in front of the reagent. After he inspected the first card tactual fashion it was removed by the experimenter while the reagent lifted his hand and arm for an interval of three seconds. By the end of this interval a new card had been substituted and as the reagent lowered his hand he found his fingers in the correct position to begin reading the next syllable. An interval of six seconds was given between series presentations. A series was considered learned when the reagent was able to anticipate the syllables correctly. After the learning, the reagent recited the syllables, spelling each one, and then gave as complete an introspection as possible upon the learning and upon the immediate recall. Twenty-four hours after the original learning the reagent was asked to recall the syllables and to introspect on this delayed recall.

In the auditory presentations the experimenter read the syllables as distinctly as possible, without spelling the letters, and at three-second intervals, allowing six seconds between series presentations. Introspections were obtained after an immediate and after a twenty-four-hour delayed recall.

The learning was done throughout under optimal laboratory conditions. A second series of syllables was not learned until the preceding series had been recalled for the last time. Our rather slow presentation was a feature of experimentation introduced in order to enable the reagent to give more detailed introspective descriptions of his learning than would have been possible if he had felt hurried. We were not interested in the learning process *per se*.

TYPICAL INTROSPECTIVE DATA

Our introspections were so long and detailed, some of which covered four or five typewritten pages, that it is here impossible to present more than one complete introspection from each reagent; but the reader will be able to grasp some-

thing of the great detail into which the observers carried their introspective descriptions and will readily understand why it has been possible to obtain results of a fairly elaborate character.

1. *Observer B.* [Parentheses indicate the reagent's interpretations of his own mental processes after they had taken place. Brackets indicate comments inserted by the editors. Each introspection is numbered for the purpose of reference.]

"Was aware of the task in terms of kinæsthetic tensions centered about my eyes, brows, shoulders, left arm and hand, together with focal auditory perceptions of the experimenter's instructions and incipient tactual and motor imagery of masses of points on a dimly localized tag-board beneath my fingers. For an instant there was an entire exclusion of other processes. (These experiences meant to me both an attitude of acceptance and of expectation.) As the series was presented I was first conscious of blunt tactual sensations and of finger movements. Then these vague points became grouped into spacial arrangements which latter constituted my tactual perceptions of the letters. As the grouping took place I was less conscious of the individual points, and became aware of a broadening of the scope of tactual attention in which all of the points of a given letter stood out with approximately equal distinctness. At the final stage of a perception that part of a letter at which a point is missing stood out in focal consciousness, or the outstanding feature was a 'bar' made by two or more points in a line and extending in a certain direction—horizontal, vertical, oblique down and to the left, or what not. At times the length of the bar was the focal feature here, and at other times the direction of the bar was the focal feature. In still other instances the outstanding feature of the perception finally became an angle formed by a group of points. For example my perception of 'c' in one of the syllables consisted of a right angle which opened to the left and whose apex was pointing to the right. In 'd' the right angle opens to the left but the apex points upward and to the right. These features stood out in terms of tactual and

kinæsthetic imagery. The awareness of an angle consisted first of a combined tactual-kinæsthetic perception of the lower end or side; the perception always began at the bottom and developed upward and to the right in the direction of finger movement. There then developed incipient finger and arm movements of tracing the right angle. In letters like 'm' and 'p,' which if solid would make a similar angle kinæsthetic imagery, appeared with the movement longer on one side. The perception of each letter also involved incipient tactual-motor imagery of finger and arm movements having to do with punching these letters by the hand method of stylus and slate. This imagery was always more distinct in such letters as did not appear in the context for some little time."

"During the process of learning each letter lingered in consciousness momentarily, followed by vocal-motor imagery. As the vocal-motor imagery developed in each instance the tactual-motor features began to disappear. Consciousness of any syllable as a whole was entirely vocal-motor-auditory. During the intervals between presentations I was engaged in repeating the preceding syllables vocal-motor fashion. I noticed that in retaining the syllables the last feature of the tactual-kinæsthetic perception to disappear was invariably a single, dominating, incipient finger and arm movement. As the presentations continued I found myself trying to anticipate the syllables, using auditory-vocal-motor imagery whenever possible. This method proved more efficient because tactual-kinæsthetic imagery involved the details of three letters while the former imagery involved a simple sound or incipient throat movement. Only when I failed to anticipate a syllable in vocal-motor fashion did I find myself resorting to the slower method of using tactual-motor imagery. I learned the first and last syllables at the outset and the middle ones last."

"During the immediate recall I was first aware of the 'bih' in terms of auditory imagery in rising inflection as if I were about to ask the question 'How do you pronounce it?' As the vocal-motor-auditory imagery developed there also ap-

peared rather definite tactual-motor imagery of the syllable in which latter imagery the individual letters stood out prominently but only for a brief instant. There then occurred a schematic grouping of the syllables in terms of incipient movements of my shoulders as if throwing the subject matter of the series into separated spaces; and with each rhythmic emphasis in the motor tendencies I had the bare beginnings of auditory imagery of the syllables themselves. This schematic grouping arranged the first four syllables into one group, the next four into a second group and the remaining two in a third group. In anticipating the syllables, vocal-motor-auditory fashion, this schematic kinæsthesi^s was intensified at the beginning of each group. The second, third, and fourth syllables appeared in vocal-motor imagery, with no tactual-motor tendencies to spell out the letters until I spelled them for the experimenter. Fleeting and schematic imagery of letters came in tactual-motor fashion wherever there was difficulty in recalling the syllables." [Six presentations were required for the learning and the observer recalled the syllables correctly save for one letter in one syllable.]

2. Delayed recall: "First there appeared a diffused motor consciousness of strains about the brows, throat and chest; motor and tactual imagery appeared of my arms outstretched before me and of making movements of investigating Braille syllables. The first syllable came readily in vocal-motor imagery (suggested by the tactual-motor attitude just described). There was a slight tendency to translate the 'b' of 'bih' into tactual-motor imagery. The three syllables which followed came in auditory-vocal-motor imagery and with very little effort. As I recalled the fourth there first came a schematic visual-kinæsthetic image of a printed 'L'; no paper was visible in this image and no background save the 'nothingness' which is always associated with my visual imagery. The fifth syllable was hard to recall. At first I had 'vez' in auditory imagery which I found myself at once correcting to 'veh,' tactual-motor fashion. The antecedent of this correction consisted of developing tensions about the forehead

and trunk which grew more intense as my attention began to shift toward the act of anticipating the next syllable. There was kinæsthetic imagery of jerking my arm back; breathing seemed to be checked momentarily, with tensed diaphragm and a vigorous vocal-motor-auditory: 'No.' The next syllable, 'pog,' appeared in auditory vocal-motor imagery, together with incipient tendencies to vocalize it before I was certain that it was correct. Certainty here seemed to consist of the persistence of the auditory-vocal-motor imagery of the syllable, together with a developing tactual-motor image of the three letters and a tendency to smile. Then I paused; sudden tensions developed about the forehead, trunk, and especially in the jaws and throat; there came fleeting auditory imagery: 'What next?' I had tendencies to move my arm and hand as if feeling of letters (this together with the tensions constituted an effort to recall the next syllable.) Then I had tactual imagery of the laboratory table, cards, chair, and auditory imagery of the experimenter's voice. (These latter constituted a consciousness of the task.) Then I found myself exclaiming vocal-motor fashion, 'Oh,' as 'double U' appeared in vocal-motor-auditory imagery. Then the syllable 'nuz' suddenly appeared and I at once found myself vocalizing it. The remainder of the series came easily and in auditory-vocal-motor imagery."

3. *Observer A.* [Syllables were dop, jan, vum, qoh, qez, pif, xap, loy, pef, hov and were thus arranged in a series for the purpose of watching the behavior of synæsthetic imagery.]

"I first went through the series with the intent of becoming generally familiar with the syllables, and of constructing a pronunciation for them or a name for each. I grouped the first three together in terms of vocal-motor-auditory imagery, thus, 'dop-jan-vum.' I paid no attention to the tactual-kinæsthetic elements in the learning or in the perceptions of the letters. As fast as I inspected each syllable the appropriate synæsthetic visual image appeared at my finger tips, the coloring and brightness of the imagery being determined by the letter. When I then found myself vocalizing the syllable,

the syllable itself tended to take on the color of the initial letter. As my attention shifted from the procedure of inspecting the letters, tactual-kinæsthetic fashion, the visual imagery which at all times remained dominant in consciousness shifted to the center of my field of vision. Throughout, the tactual-motor processes were dim, vague, indescribable experiences of which I know nothing except in terms of their visual associates. [In other words the former were cues for the appearance of the latter.] It was not until the third repetition that I was able to anticipate any more than the first three syllables. My learning procedure consisted chiefly of visualizing the color for each syllable in a schema. The first three syllables assumed their place in a straight line to the left in the schema, and along with this there took place auditory-vocal-motor imagery of them. The remaining syllables were learned when I could fix a place for them in this visual schema. The fourth syllable to be thus placed in the schema was the eighth, whose color was brighter than its neighbors; this syllable occupied an elevated position in the form and considerably to the right of the first three. Between them and to the left of the eighth were spaces of neutral gray into which I later fitted the remaining syllables. After the first four or five presentations I changed my *Aufgabe* from that of retaining to that of anticipating the syllables and my method, as before, was almost entirely visual."

"As each syllable was inspected tactual-motor fashion my attention was centered visually upon the tips of my fingers; with a certain amount of finger-movement colors began to appear at my finger tips; these colors were my awareness of the letters as such; just as soon as these colors began to develop I shifted my line of regard to the center of a visual field extended out before me in space and there tried to visualize the syllable in color."

"When I centered my attention upon one section of the form, it only was clearly 'seen'; in indirect vision I could 'see' adjacent sections. The brighter or more persisting colors of these sections tended to draw attention away from

the section upon which I was focusing my attention at the time. This often resulted in confusion. In the process of trying to anticipate the syllables it frequently happened that more than one color would thus attract my attention before I succeeded in clarifying a dim section in the form. I also found myself confusing colors for individual letters with colors for entire syllables. I would then have to wait for the next tactual-motor presentation in order to ascertain which color stood for a letter and which for a syllable. I had a great deal of trouble with 'pif.' The color for this syllable persistently appeared out of order."

"As the form developed it became stable and the sections standing for individual syllables were definitely differentiated. The first three syllables formed a straight line of three colors to the left; the 4th, 5th and 6th assumed a position, in colors, along a downward slant toward the right, beginning where the third syllable left off. The 7th was learned last and came to occupy a dip in the form below the others; the 8th appeared as a high crest to the right of the dip and the 9th and 10th assumed a slanting position at the right end."

"I announced that the learning was complete as soon as I was able to follow along this visual form just ahead of the tactual-motor presentation of the syllables. I fixated each section of the form and translated the color vocal-motor fashion. It was then verified by a brightening process which the colors underwent when I inspected the syllables with my fingers."

"In the immediate recall I found my visual attention centered upon the left end of this visual schema. The appearance of the first three syllables in a straight line meant to me that I had learned these together and with ease; they were dominantly grayish-green in color, shading toward a lighter tint at the extreme left; the lighter left end told me at once that the syllable began with 'd.' The visualized 'd' suggested at once the syllable 'dop,' which in turn suggested the next two syllables with no necessity of translating, consciously, from the visual schema. But as I vocalized these

syllables the colors of this section of the schema brightened. I then found myself fixating the downward slant of the form; the first section of this region was colored by the letter 'q'; the second was colored by the 'z' sound in the syllable, and the third was colored by the 'x.' I fixated my attention first upon one of these colors and then upon the other. Then I translated these colors into their appropriate letter-sounds and subsequently, by means of a trial and error method, pronouncing different sounds to myself, I built up the syllables, 'qoh,' 'qez' and 'xap.' The final recall came in auditory-verbal imagery together with a brightening of the colors in the form. In turn, the 'pif' and 'loy' stood out in their own distinct colors; then at the last, 'pef' and 'hov.' In no instance was a syllable recalled first in vocal-motor fashion. Each recall was constructed rather laboriously from the verbal suggestions which came from the localized colors of the form."

4. Delayed recall: "The intent to recall the syllables of the day before led at once to colored visual imagery of the form before described. I found myself fixating the extreme left end and then moved my line of regard to the right over the first three sections which formed a straight line. This triple section was a dark, grayish-green, but lighter at the left end. I found myself saying 'd' in vocal-motor imagery as I fixated the lighter portion at the left and then, suddenly, there came the vocal-motor-auditory imagery of 'dop,' 'jan' and 'vum.' Next, moving my line of regard downward over the oblique slant which marked the next large section in the form, I noticed that the first letter of each of the next two syllables was 'q,' because the color of the form was a dark, brownish-green. As I vocalized the 'q' there at once followed the vocal-motor 'ez' together with the colors for 'e' and 'z' which appeared in the lower half of my field of vision and floated upward, fitting into their appropriate places in the form. I then found myself repeating 'q' again in vocal-motor imagery; then I had 'o' both in vocal-motor and visual imagery, the color for the 'o' taking its place next to

the 'q' in the form. Next the syllable 'pif' came easily for I could see all three letters standing out in terms of their colors. I then saw the 7th syllable as a very dark, brown section in the form but I could get no verbal imagery from looking at this color. Next my visual attention was claimed by 'loy' which stood out as the high crest or shoulder in the form; this section was dominated by the smoky blue for 'l.'"

"I now have the missing syllable—it is 'xap.' The first hint of it came in terms of the light straw yellow of the letter 'a'; then came the poorly saturated reddish-brown, followed by the 'p' in simultaneous vocal-motor-visual imagery. These colors appeared in their proper sections in the form."

"I next turned my attention to the right end of the form where I saw distinctly the colors for 'pef' and for another syllable which I could not then translate. After a few seconds the syllable 'hoy' came to me, later corrected to 'hov.' In the last section of the form the dominant color stood for 'o.' For some time I fixated that small patch of color in the form, moving my line of regard over the neutral gray surroundings, hoping other colors would appear, when I found myself vocalizing 'v,' which in turn suggested the 'h.' These latter came in combined vocal-motor-auditory and visual imagery."

"(In my recall I at first reversed the order of 'qoh' and 'qez.' This was due to the fact that both syllables began with the same letter and looked just alike in the form, for in these two instances the colors of the section were determined by the initial letter of the syllable. There was no criterion by which I could at first tell which syllable was first and which second. I have no such difficulty in cases where the three letters stand out in colors in the form.)"

SUMMARY OF DATA FROM OBSERVER *B*

B's procedure in the learning consisted first of perceiving the individual letters of each syllable; secondly of grouping these letters into a word, vocal-motor and vocal-motor-auditory fashion; thirdly, of repeating these syllables over and over again, holding them in consciousness as best he could

in this fashion while he inspected two or more subsequent syllables; fourth, of anticipating the syllables in terms of vocal-motor imagery.

It is interesting to note that the dominating features of *B*'s tactual perceptions were invariably (1) motor imagery of angles or (2) motor imagery of punching the point letters (3) verbal imagery. These processes terminated any given act of perceiving and identified the letter.

As learning progressed, *B* tended to rely more and more upon vocal-motor-auditory imagery, resorting to tactual-motor imagery only when in difficulty. Tactual-motor imagery always turned out to be a laborious method of retaining the syllables for the reason that each letter had to be represented. By means of a motor schema, involving incipient shoulder movements, *B* grouped the ten syllables into 4, 4, and 2.

This grouping was rather prominent during the immediate recall. Here *B* invariably resorted to vocal-motor-auditory imagery first, and if one syllable failed to suggest the next he became conscious of the *Aufgabe* in terms of muscular strain, or of tactual-motor imagery of the table, the cards or of previous syllables. Tactual-motor imagery of syllables functioned only when auditory-vocal-motor imagery was obscure or lacking.

In the delayed recall the syllables appeared both in auditory-vocal-motor and in tactual-motor fashion. Here the latter processes were somewhat more pronounced than in the immediate recall and functioned both to supplement incomplete auditory-vocal-motor imagery and to correct wrong auditory-vocal-motor processes. The cues which aroused the imagery of the various syllables were not always obvious. The *Aufgabe* to recall readily sufficed to suggest the first syllables of the series. Usually the next three or four syllables came readily in auditory-vocal-motor fashion. Toward the latter part of the recall the syllables appeared less easily and there were frequent returns to a consciousness of the task. As far as one syllable was recalled by means of observable

cues these cues consisted wholly of auditory, tactual and kinæsthetic processes.

B learned the syllables, on the average, in six repetitions of the series.

SUMMARY OF RESULTS FROM OBSERVER *A*

A's procedure in the learning was as follows: He first inspected each syllable in tactual-motor fashion but paid no attention either to the tactual or to the motor elements as such. As soon as the points of each letter were felt, there appeared visual imagery at his finger tips; this imagery became colored as the points of the letters became grouped into characteristic formations. In other words *A* invariably perceived and recognized the letters in terms of colors which took on various shapes and sizes according to the letter-meanings. Secondly, he constructed auditory-verbal imagery of each syllable, together with a color for the syllable as a whole. At times the initial letter of the syllable determined the color, and at times each letter was represented. In other instances the color of the syllable was dominated by the vowel sound. Thirdly, he retained these syllables by fixing these colors in certain positions in a visualized schema. This process was involuntary at the outset but at once became the tool of a voluntary effort to remember the syllables. Fourth, he used this schema in anticipating the syllables in the later presentations of any series. Meanwhile tactual-motor perceptions and auditory-vocal-motor imagery were used to fill gaps in this form, to correct erroneous colors or to eliminate confusions in the colors.

The immediate recall consisted chiefly of translating the colors of the form into vocal-motor imagery. Where a syllable was represented by only one color *A* was forced to resort to vocal-motor expedients and to a trial-and-error method of completing the syllable. Where the appropriate color failed to appear and to assume its correct position in the form, whether this color stood for an initial letter or a vowel, or whether it represented an entire syllable in terms of

its initial letter, *A* was forced to try such indirect methods or to 'wait' until the appropriate colors appeared in consciousness. A color which occupied sufficient space in the form to cover the positions for three letters stood for an entire syllable. On the other hand certain syllables were represented by three colors in which case the recall was easy.

Colors which were not present in the form at the outset of the recall invariably appeared in the lower half of *A*'s field of vision, below the form, and migrated to their appropriate places in the schema itself. Auditory-verbal imagery always brightened the colors and made them more persistent.

The delayed recall resembled the immediate recall in most respects. The colors of the form were as a rule quite as vivid as on the preceding day. Here, however, the process of translating some of the syllables was more difficult owing to the fact that the associations between a single color and the remaining letters of the syllable had been lost temporarily. For the time being no amount of effort resulted in obtaining further cues. In such instances it invariably turned out that the color was not faithful to the syllable or letter, that a certain combination of letters in a particular word caused *A* to visualize a foreign or unrecognizable mixture of colors, or perhaps a certain color had faded or had otherwise changed in such fashion as would lead it to suggest either more than one letter or the wrong letter.

A required from 6-9 presentations in learning the syllables. *B* learned them more rapidly. This fact is explained on several grounds. (1) In *A*'s case the letters thus grouped into syllables in meaningless fashion tended to produce detached or dissociated colors which did not 'hang together.' As a result his consciousness at times became flooded with 'floating' colors whose combinations were unstable. This difficulty arose even during the process of learning itself and was the source of not a little confusion. (2) The colors for syllables were often dominated by the color for one letter, thus making it necessary to resort to such expedients as tactual-motor or auditory-vocal-motor imagery in retaining

the other letters; but as fast as *A* could fill out the remainder of the syllable in this fashion, the dominating color would persist in blotting out the less stable colors of the remaining letters. (3) In the act of anticipating the syllables many errors were made which had to be corrected. These errors were due to tendencies to anticipate the brighter or more stable colors out of their order in the series. (4) Attempts to fill in gaps in his form or to anticipate syllables in auditory-vocal-motor imagery inevitably dragged into consciousness additional arrays of colors which either had to be differentiated from the correct colors, in case of auditory-vocal-motor guesses, or which had to be ignored. Thus *A* was prevented from employing auditory-vocal-motor imagery in the learning unless he were certain that this imagery was correct. This difficulty was due, in general, to the fact that *A* cannot think letters, verbal fashion, in the absence of colors.

OBSERVERS *A* AND *B* COMPARED

1. Tactual and motor images other than auditory-vocal-motor were employed by *B* in the process of perceiving letters, in retaining letters whose sounds had not become familiar, and in retaining syllables whose sounds were difficult to pronounce. This same imagery was used under similar circumstances in anticipating and in recalling the syllables. In *A*'s case such imagery functioned only as a stepping stone in the arousal of colors and in no instance was it attended to as such.

2. Kinæsthetic imagery and incipient movement were employed by *B* in grouping the syllables into a schema. This grouping was done by *A* in terms of a visual schema in which each syllable assumed a definite place and took on a definite coloration.

3. *B* used auditory-vocal-motor imagery in retaining, in anticipating and in recalling the syllables. This type of imagery dominated throughout *B*'s procedure. *A* used auditory-vocal-motor imagery only in connection with visual synæsthetic colors, either in an effort to arouse colors, to strengthen them, or to translate them into language.

4. Visual imagery appeared only rarely in *B*'s case and was never used in the learning. In *A*'s case visual imagery assumed a wide variety of rôles: (1) As synæsthetic features of his 'tactual-motor' perceptions of the letters, in which cases the colors identified the letters; (2) as synæsthetic features of vocal-motor-auditory imagery of syllables or letters; (3) as detached symbols for letters or for syllables in the absence of other processes; (4) as sections in a schema or form, standing for a syllable or an entire series of syllables; (5) as cues by means of which syllables or letters were anticipated; (6) as cues by means of which syllables or letters were retained and recalled.

SUMMARY OF RESULTS FROM AUDITORY PRESENTATIONS

B's procedure in learning nonsense syllables with an auditory presentation was confined wholly to the use of auditory-vocal-motor imagery. Upon perceiving the syllables he translated them into auditory-vocal-motor imagery and repeated them over and over again, holding as many syllables in consciousness as possible before the next syllable was given. This method was soon changed to that of anticipating the syllables, auditory-vocal-motor fashion. Whenever one syllable failed to suggest another he found himself recalling syllables which came earlier in the series or anticipating in advance such syllables as came later in the series. If these expedients failed he became absorbed momentarily in masses of motor imagery and strains which constituted effort and impatience.

A's synæsthetic phenomena began to function at the outset in learning syllables by the auditory method. Auditory perceptions consisted in large measure of flashes of brightness and of color, determined either by the initial letter of a syllable or by some other prominently sounding letter. These flashes of color ultimately became fixed in a form as in the case of tactual presentation. *A*'s visual imagery became fixed by repetition as did *B*'s auditory-vocal-motor imagery.

As before, those syllables were learned first whose colors were brightest and the symbolic representation of such syl-

lables appeared as shoulders or peaks in the schema. Anticipation of syllables and the recalls took place as in the previous experiment. When this observer was about to recall any given set of syllables he was utterly lost unless the colors appeared in connection with the intent to recall. In such instances in which the colors were stable *A* found it quite as easy to repeat the syllables backwards as it was to repeat them in the order learned. On the other hand, his method of employing colors caused him numerous difficulties.

We have already mentioned several reasons for this. In the present experiment other difficulties came to light. (1) The color for the initial letter of a nonsense syllable may not be as definite, as well saturated or exactly the same quality as the color which ordinarily stands for that letter for the reason that the letter itself represents an entire syllable. Certain letters are known not only by means of their hue or brightness but by means of their shape. In case a letter represents an entire syllable its shape is changed to cover, in the schema, sufficient space to be occupied by three letters. (2) The colors for letters are influenced by the setting in which those letters appear, and by the amount of emphasis which the letter happens to receive in any particular context. (3) Certain letters take on varying colors or shades of brightness according to the different situations in which they function.

On the whole, however, the colors employed by *A* in these investigations agree with the colors for these letters, reported two and three years previous. But any variations in colors so far discovered in our investigations clearly point to the fact that where meanings remain the same so do the colors and where meanings change, so do the colors.

In the absence of a color or definite brightness, *A*'s implicit *Aufgabe* to recall a given syllable consists of visual fixation upon a vacant section in the form. First his line of regard is rigidly centered upon the extreme left-hand portion or edge of this vacant section and is then moved across toward the right.

This act may be repeated several times. Meanwhile the entire form tends to split up, requiring considerable eye-movement and vocalization to keep it intact and in the center of the field of vision. Any fluctuation in shape or incipient change in color or brightness at once claims *A's* attention. Perhaps this incipient change is the forerunner of a definite color or brightness which leads to the desired verbal process and hence to the desired recall. Perhaps the vacant section in the form fails to 'fill in.' In either case the change comes of itself. Voluntary effort is invariably an indirect procedure consisting of motor-visual factors such as eye-strain, eye-movement, sudden motor-visual fixations upon changes of color and brightness in the form itself, strains in the throat, chest and arms.

On the whole, then, *A's* procedure in this experiment did not differ materially from his procedure in the tactual series other than in the method employed in arousing the original colors. In either case learning took place in terms of the manipulation of colors and these colors were determined by the letters and not by the mode of presentation. In both instances the colors were identical with those which symbolize the same letters in *A's* everyday mental life, with the exceptions above mentioned.

B's method in this experiment was likewise similar to his method in the previous experiment with the exception that, in the latter, tactual-motor processes figured in retaining, in anticipating and at times in recalling such syllables as failed to appear in auditory-vocal-motor fashion.

A comparison of *A's* performances with *B's* in this latter experiment confirms our results from the tactual presentations. In *B's* learning, one auditory-vocal-motor process led to another. These processes were his only cues. *A* had no tactual imagery. *A's* auditory-vocal-motor imagery was used only indirectly. In *A's* case colors were used at times as cues in arousing auditory-vocal-motor imagery and the latter was used as a frequent cue for the arousal of colors and for the strengthening of colors. There was no analogous

process in *B*'s procedure unless it could be said that one auditory-vocal-motor image suggested the next and that the next in turn reinforced the first. At any rate, in *A*'s case this mutual reinforcement or facilitation process which went on between colors and inner speech is a characteristic feature of his synæsthetic phenomena and a function which strikingly reminds us of reciprocal innervation.

In this facilitation process we find another characteristic of synæsthetic phenomena. Both the auditory-vocal-motor process and the visual image play the double but successive rôle of stimulus and response. For example, the appearance of a brown color in *A*'s visual form sets off the vocal-motor image of 'm' whereupon the brown color itself becomes more stable and definite. On the other hand if a certain color fails to develop to that stage of definiteness which will enable the reagent to translate it into its appropriate vocal-motor associate he resorts to vocal-motor imagery of various letters in order to find the associate which will definitize the color for future use. At times *A* finds himself vocalizing in order to arouse a desired color. Here the auditory-vocal-motor process seems to possess a stimulus function and the color becomes the response. The transition from visual to vocal-motor image is the slower of the two and is a process of translating the visual symbol, now detached from its vocal-motor associate, into the vocal-motor process. The transition from vocal-motor to visual process is exceedingly rapid and consists only of a shift of attention from the vocal-motor to the visual feature. The former seems to 'drag in' the latter. The vocal-motor feature, however, is never definite in itself and is known to the reagent only in terms of the characteristic behavior of the visual associate. By this latter he can tell definitely when the former appears and disappears. The vocal-motor-auditory feature does not exist alone in consciousness; it is noticeable whenever the visual feature is present to interpret it. On the other hand the visual feature often stands alone in consciousness. Such detached visual associates float about in *A*'s field of vision and are controlled

by eye-movement. By having recourse to the vocal-motor-visual combination the visual feature is rendered stable.

The two sorts of voluntary control differ in that arousing an auditory-vocal-motor process by way of the visual begins with a tentatively dissociated visual image while the act of recalling a visual image takes place at once with the recall of an auditory-vocal-motor process. The latter is never dissociated from the visual accompaniment, *i.e.*, it cannot stand alone in consciousness. The direction of *A's* attention as determined by the implicit purpose of the moment directs the order of appearance of verbal and visual process.

SUMMARY AND CONCLUSIONS

1. Synæsthetic phenomena appear throughout the learning, in *A's* case, as follows:

- (a) in perceiving the letters and syllables;
- (b) in retaining letters and syllables during the presentation of the series;
- (c) in anticipating letters and syllables during the presentations;
- (d) in immediate recall;
- (e) in delayed recall.

2. Synæsthetic imagery functions in part as the content of self-imposed tasks. These tasks may be conscious or deliberate or they may be implied in the behavior of the reagent.

3. Synæsthetic visual imagery delays the process of learning owing to the fact (a) that a syllable is frequently represented only by the color of a dominant letter, (b) that auditory-vocal-motor guesses cannot be made without increasing the variability and complexity of this synæsthetic imagery, (c) that the visual associates become detached from their parent processes and fail to arouse the latter during recall, (d) that synæsthetic colorations vary in different situations and contexts.

4. *A's* learning has been checked in every respect against *B's* and throughout no functional differences are apparent. A comparison of the two observers shows that such differences

as are found between them are concerned only with contents.

B perceives letters tactual-motor fashion. Here the spacial grouping of letters develops in terms of bars and angles with the aid of kinæsthetic imagery and incipient movement. *A* perceives letters with the aid of synæsthetic visual imagery. Here tactual and motor factors always remain in an obscure and indefinable background.

B perceives syllables in terms of verbal imagery. *A* perceives them in terms of verbal processes plus synæsthetic visual imagery. Here, as well, the auditory-vocal-motor features remain in the background.

B perceives syllables directly in auditory fashion. *A* perceives the spoken syllables in terms of flashes of color and brightness.

The learning progressed in like fashion in both reagents as far as its functional aspects are concerned. Both were doing the same sorts of things throughout but where *B*'s mental contents were tactual, motor, and auditory, *A*'s were dominantly visual. The fact that *A* uses stereotyped visual imagery and the fact that he is synæsthetic resulted in certain difficulties of learning on the one hand and in a certain ease of recall on the other which were not characteristic of *B*; but these features of the learning turned out to be incidental rather than inherent in the learning process as such. They were due to the differences in mental contents between the two reagents and not to differences in basic mental functions. Such functions as attention, voluntary control, retention, anticipation, recall, association, the use of schema and the like took place in identical manner in the two reagents, barring incidental differences found in the behavior of differing mental contents.

5. *A*'s synæsthetic phenomena are here identical in perceiving and in remembering, barring such changes as occur with changes in meaning.

6. We conclude that, in the process of learning, *A*'s synæsthetic phenomena are normal functions whose contents,

alone, are unusual. These phenomena are as essential to his learning as processes of perceiving and recalling are essential to *B*'s learning. Indeed, *A*'s synæsthetic phenomena are his methods by which he perceives and recalls.

7. Synæsthetic phenomena are not confined to the realm of perception alone in *A*'s case. They are quite as evident in his processes of thinking. They are throughout concerned with the development of meaning. In this case of learning meanings were confined to letters and to sounds.

8. Two sets of factors in the behavior of *A*'s synæsthetic phenomena point to the view that synæsthesia is a form of conditioned reflex: (1) The parent tactual, motor or auditory-vocal-motor process acts upon the visual associate in a manner functionally resembling facilitation; (2) the colored associate is a stereotyped response to the parent process as a stimulus. The fact that the colored associate may come to function as a stimulus for the arousal of the parent process does not seem to militate against this view since the conditioned reflex as a type phenomenon need not be confined to the realm of external stimulus and explicit muscular response.

9. Voluntary control of a mental process in each reagent was an indirect process, *i.e.*, a given mental content was controlled indirectly by means of an antecedent sensory or ideational cue together with eye-movement or other incipient motor process.

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